I. PATENT ABSTRACTS OF JAPAN

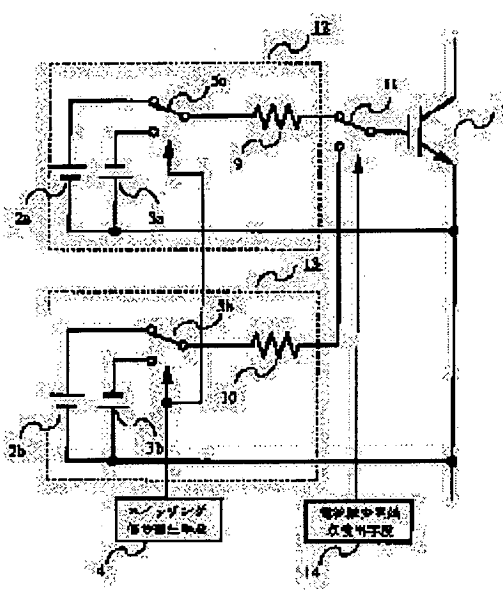
(11)Publication number : **10-023743**
(43)Date of publication of application : **23.01.1998**

(51)Int.CI. H02M 1/08
H02M 1/08
H02J 1/00
H02M 7/537

(21)Application number : **08-176475**
(22)Date of filing : **05.07.1996**

(71)Applicant : **MITSUBISHI ELECTRIC CORP**
(72)Inventor : **KIMATA MASAHIRO**

(54) DRIVE CIRCUIT OF SEMICONDUCTOR DEVICE



(57)Abstract:
PROBLEM TO BE SOLVED: To obtain a drive circuit which facilitates both the suppression of a voltage surge and the reduction of a switching loss and, further, can be applied to all IGBT(insulated gate self-extinguishing type) devices.
SOLUTION: A drive circuit is composed of a 1st drive means 12 which drives an IGBT device 1, a 2nd drive means 13 which drives the IGBT device at a speed slower than the speed of the 1st drive means 12, a switching means 11 by which the output of the 1st drive circuit 12 and the output of the 2nd drive circuit 13 are switched from one to the other and supplied to the gate of the IGBT device 1 and a current decrease start point detecting means 14 which detects the time point when the current decrease starts in a transition period from a 1st period in which the collector current of the IGBT device changes gradually to a 2nd period which follows the 1st period and in which the collector current changes sharply when the IGBT device 1 is turned off. The switching means 11 is operated by the output of the current decrease start point detecting means 14 so as to use the 1st drive means 12 in the 1st period and use the 2nd drive means 13 in the 2nd period.

LEGAL STATUS

[Date of request for examination]	06.06.2001
[Date of sending the examiner's decision of rejection]	
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	3421507
[Date of registration]	18.04.2003
[Number of appeal against examiner's decision of rejection]	
[Date of requesting appeal against examiner's decision of rejection]	
[Date of extinction of right]	

CLAIMS

[Claim(s)]
[Claim 1] In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The 1st driving means which drives said insulated-gate form self-**** component, and the 2nd driving means which drives said insulated-gate form self-**** component rather than said 1st driving means at a low speed, A switching signal generating means to supply a signal to said 1st driving means and said 2nd driving means, A switch means to switch the output of said 1st driving means, and the output of said 2nd driving means, and to supply said control electrode, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. The drive circuit of the semiconductor device characterized by operating said switch means with the output of said current reduction start point detection means so that said 2nd driving means may be used in said 2nd period using said 1st driving means in said 1st period.
[Claim 2] In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the direct current voltage supply for off which supply OFF state voltage to said control electrode, The on-off switch means which switches said direct current voltage supply for ON and said direct current voltage supply for off, A switching signal generating means to supply a signal to said on-off switch means, The 1st gate resistance connected to said on-off switch means, and the 2nd gate resistance which is connected to said on-off switch means, and has bigger resistance than said 1st gate resistance, A switch means to switch said the 1st gate resistance and said 2nd gate resistance, and to connect with said control electrode, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. The drive circuit of the semiconductor device characterized by operating said switch means with the output of said current reduction start point detection means so that said 2nd gate resistance may be used in said 2nd period using said 1st gate resistance in said 1st period.
[Claim 3] In the drive circuit connected to the control electrode of the insulated-gate form self-

**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the 1st direct current voltage supply for off which supplies OFF state voltage to said control electrode, The 2nd direct current voltage supply for off which supplies OFF state voltage to said control electrode, and has an electrical potential difference smaller than said 1st direct current voltage supply for off, The switch means which switches said 1st direct current voltage supply for off, and said 2nd direct current voltage supply for off, The on-off switch means which switches said direct current voltage supply for ON, and the output of said 1st switch means, A switching signal generating means to supply a signal to said on-off switch means, The gate resistance connected between said on-off switch means and said control electrodes, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. The drive circuit of the semiconductor device characterized by operating said switch means with the output of said current reduction start point detection means so that said 2nd direct current voltage supply for off may be used in said 2nd period using said 1st direct current voltage supply for off in said 1st period.

[Claim 4] In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The source for ON of a direct current which slushes a current into said control electrode, and the 1st source for off of a direct current which begins to pass a current from said control electrode, The 2nd source for off of a direct current where begin to pass a current from said control electrode, and a current value is smaller than said 1st source for off of a direct current, The switch means which switches said 1st source for off of a direct current, and said 2nd source for off of a direct current, An on-off switch means to switch said source for ON of a direct current, and the output of said 1st switch means, and to connect with said control electrode, A switching signal generating means to supply a signal to said on-off switch means, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. The drive circuit of the semiconductor device characterized by operating said switch means with the output of said current reduction start point detection means so that said 2nd source for off of a direct current may be used in said 2nd period using said 1st source for off of a direct current in said 1st period.

[Claim 5] In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the direct current voltage supply for off which supply OFF state voltage to said control electrode, The on-off switch means which switches said direct current voltage supply for ON and said direct current voltage supply for off, A switching signal generating means to supply a signal to said on-off switch means, The gate resistance connected between said on-off switch means and said control electrodes, The capacitor which was connected to said control electrode and which switched and was connected

with the means and said switch means between the ends of said main electrode, The voltage adjustment means connected to said switch means and juxtaposition, The electrical potential difference impressed to said control electrode It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case it is made to fall and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. The drive circuit of the semiconductor device characterized by operating said switch means so that said control electrode and said capacitor may be connected in said 2nd period with the output of said current reduction start point detection means.

[Claim 6] The drive circuit of the semiconductor device according to claim 1 to 5 characterized by consisting of a comparison means by which said current reduction start point detection means measures an electrical-potential-difference detection means to detect the electrical potential difference of the control electrode of said insulated-gate form self-**** component, the source of reference voltage, and the output of said electrical-potential-difference detection means and the output of said source of reference voltage.

[Claim 7] The drive circuit of the semiconductor device according to claim 1 to 5 characterized by consisting of a comparison means by which said current reduction start point detection means measures a current detection means to detect the current which flows to the control electrode of said insulated-gate form self-**** component, the source of reference voltage, and the output of said current detection means and the output of said source of reference voltage.

[Claim 8] The drive circuit of the semiconductor device according to claim 1 to 5 characterized by to consist of a comparison means to by_which said current reduction start point detection means measures an electrical-potential-difference detection means detect the electrical potential difference of the control electrode of said insulated-gate form self-**** component, a differential means differentiate the output of said electrical-potential-difference detection means, the source of reference voltage, and the output of said differential means and the output of said source of reference voltage.

[Claim 9] The drive circuit of the semiconductor device according to claim 1 to 5 characterized by to consist of a comparison means to by_which said current reduction start point detection means measures a current detection means detect the current which flows the control electrode of said insulated-gate form self-**** component, a differential means differentiate the output of said current detection means, the source of reference voltage, and the output of said differential means and the output of said source of reference voltage.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention] This invention relates to the gate drive circuit [it is possible to control the electrical-potential-difference surge under turn-off actuation especially, and] which can reduce switching loss about the gate drive circuit of the IGBT component (Insulated Gate Bipolar Transistor, insulated-gate form self-**** component) which is a kind of the semiconductor device for switching.

[0002]

[Description of the Prior Art] Drawing 18 is the block diagram showing the drive circuit of the semiconductor device stated to JP,5-328746,A, in drawing, 1 is an insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode, and 1a is [the 1st main electrode and 1c of a control electrode and 1b] the 2nd main electrode. Henceforth, collector 1b and 2nd main-electrode 1c are called [the insulated-gate form self-**** component 1 / the IGBT component 1 and control-electrode 1a] emitter 1c for gate 1a and 1st main-electrode 1b for simplification. The direct current voltage supply for ON which supply an electrical potential difference for 2 to turn on the IGBT component 1, The direct current voltage supply for off which supply an electrical potential difference for 3 to turn off the IGBT component 1, A switching signal generating means to generate the signal with which 4 turns on / turns off the IGBT component 1, An on-off switch means for 5 to switch the direct current voltage supply 2 for ON and the direct current voltage supply 3 for off with the output of the switching signal generating means 4, and to impress an electrical potential difference to gate 1a of the IGBT component 1, and 6 are gate resistance switch means which switch gate resistance. The gate resistance switch means 6 consists of switch means 11 with resistance 9 and resistance 10. Moreover, a current detection means to detect the current to which 7 flows for the IGBT component 1, and 8 are control means which control the gate resistance switch means 6 by the output of the current detection means 7.
[0003] Drawing 19 is a flow chart which shows the control approach of a control means 8. In this control approach, when it distinguished whether a flow current would be smaller than a reference current value, and smaller [than the reference current value] and it is distinguished by the output of a current detection means 7 to detect the flow current of the IGBT component 1, the signal which switches gate resistance greatly is outputted and processing is ended with it. When smaller [than a reference current value] and it is distinguished, processing is ended without outputting the signal which switches gate resistance greatly.
[0004] Next, actuation is explained using drawing 18, drawing 19, drawing 20, and drawing 21. If the switching signal generating means 4 outputs an ON signal, it is switched to the direct current voltage supply 2 for ON, ON state voltage is impressed to gate 1a of the IGBT component 1 through the gate resistance switch means 6, and the on-off switch means 5 turns on the IGBT component 1. When the IGBT component 1 is an ON state, it distinguishes whether the flow current value with which the current detection means 7 detected the flow current of the IGBT component 1, and the control means 8 was detected is smaller than a reference current value. When the flow current value was smaller than the reference current value and it is distinguished, a control means 8 supplies a resistance switch signal to the gate resistance switch means 6, it switches it so that gate resistance may become large, and switches a means 11. It specifically changes it into an open condition for the switch means 11 to have been in the short circuit condition, and only resistance 9 is used as gate resistance. Subsequently, if the switching signal generating means 4 outputs an off signal, it is switched to the direct current voltage supply 3 for off, OFF state voltage is impressed to gate 1a of the IGBT component 1 through the gate resistance switch means 6, and the on-off switch means 5 turns off the IGBT component 1. Under the present circumstances, since the switch means 11 is in an open condition, turn-off actuation is performed only by resistance 9. Moreover, when the control means 8 had the flow current value larger than the reference current value and it distinguishes, the short circuit condition of the switch means 11 is maintained, and the combined resistance of resistance 9 and resistance 10 is used as gate resistance. Since parallel connection of resistance 9 and the resistance 10 is carried out, combined resistance becomes smaller than resistance 9. Therefore,

according to this actuation, gate resistance becomes large only when a flow current value is smaller than a reference current value.

[0005] Drawing 20 is drawing having shown the effectiveness which the size of gate resistance exerts on the switching waveform at the time of the turn-off of the IGBT component 1. The collector current Ic which is a flow current of the IGBT component 1, the collector to emitter voltage Vce of the IGBT component 1, and switching loss P of the IGBT component 1 are illustrated, drawing 20 (a) shows the case where gate resistance is small, and drawing 20 (b) shows the case where gate resistance is large, respectively. Since the percentage reduction of the collector current Ic at the time of a turn-off becomes loose so that gate resistance is enlarged, the electrical-potential-difference surge between the collector emitters produced by impressing the percentage reduction of said collector current Ic to a wiring inductance is reduced. However, since the rate of increase of collector to emitter voltage Vce also becomes loose at coincidence, switching loss P expressed with the multiplication integral value of collector current Ic and collector to emitter voltage Vce increases. As mentioned above, although control of an electrical-potential-difference surge is realizable by enlarging gate resistance, there is a fault that switching loss increases.

[0006] Here, the turn-off property of the IGBT component 1 is considered. It is dependent on collector current Ic, and the fall time tf which is time amount after collector current Ic begins reduction at the time of the turn-off of the IGBT component 1 until it ends reduction has the property of the increasing function of Ic. Drawing 21 showed this. a high current region -- a component property -- the fall time tf -- long -- becoming -- being inevitable (collector current/fall time) -- since the current percentage reduction expressed becomes small, an electrical-potential-difference surge stops posing a problem On the contrary, since the pulse decay time tf becomes short and an electrical-potential-difference surge becomes large, the cure against reduction is needed in a small current region. Therefore, an electrical-potential-difference surge can be controlled by enlarging gate resistance and lengthening the pulse decay time tf, only when a flow current is a small current region. Under the present circumstances, since gate resistance is made small in the high current region, switching loss does not increase.

[0007]

[Problem(s) to be Solved by the Invention] Since the drive circuit of the conventional semiconductor device is constituted as mentioned above and the IGBT component was premised on the component property which the fall time increases with the increment in collector current, there was a trouble of being applicable only to a specific component. Moreover, in the drive circuit of the conventional semiconductor device, since the minimum value of gate resistance is decided for control of an electrical-potential-difference surge, gate resistance cannot be made small more than a limit of an electrical-potential-difference surge. For this reason, there was a trouble that the cure which makes gate resistance small and reduces switching loss could not be performed effectively.

[0008] This invention was made in order to cancel the above troubles, and it aims [that it is compatible in control of an electrical-potential-difference surge, and reduction of switching loss] possible at obtaining the drive circuit of a semiconductor device applicable to all IGBT components.

[0009]

[Means for Solving the Problem] The drive circuit of the semiconductor device concerning the 1st configuration of this invention In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes

by the electrical potential difference impressed to a control electrode The 1st driving means which drives said insulated-gate form self-**** component, and the 2nd driving means which drives said insulated-gate form self-**** component rather than said 1st driving means at a low speed, A switching signal generating means to supply a signal to said 1st driving means and said 2nd driving means, A switch means to switch the output of said 1st driving means, and the output of said 2nd driving means, and to supply said control electrode, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. With the output of said current reduction start point detection means, said switch means is operated so that said 2nd driving means may be used in said 2nd period using said 1st driving means in said 1st period.

[0010] The drive circuit of the semiconductor device concerning the 2nd configuration of this invention In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the direct current voltage supply for off which supply OFF state voltage to said control electrode, The on-off switch means which switches said direct current voltage supply for ON and said direct current voltage supply for off, A switching signal generating means to supply a signal to said on-off switch means, The 1st gate resistance connected to said on-off switch means, and the 2nd gate resistance which is connected to said on-off switch means, and has bigger resistance than said 1st gate resistance, A switch means to switch said the 1st gate resistance and said 2nd gate resistance, and to connect with said control electrode, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. With the output of said current reduction start point detection means, said switch means is operated so that said 2nd gate resistance may be used in said 2nd period using said 1st gate resistance in said 1st period.

[0011] The drive circuit of the semiconductor device concerning the 3rd configuration of this invention In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the 1st direct current voltage supply for off which supplies OFF state voltage to said control electrode, The 2nd direct current voltage supply for off which supplies OFF state voltage to said control electrode, and has an electrical potential difference smaller than said 1st direct current voltage supply for off, The switch means which switches said 1st direct current voltage supply for off, and said 2nd direct current voltage supply for off, The on-off switch means which switches said direct current voltage supply for ON, and the output of said 1st switch means, A switching signal generating means to supply a signal to said on-off switch means, The gate resistance connected between said on-off switch means and said control electrodes, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control

electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. With the output of said current reduction start point detection means, said switch means is operated so that said 2nd direct current voltage supply for off may be used in said 2nd period using said 1st direct current voltage supply for off in said 1st period.

[0012] The drive circuit of the semiconductor device concerning the 4th configuration of this invention In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The source for ON of a direct current which slushes a current into said control electrode, and the 1st source for off of a direct current which begins to pass a current from said control electrode, The 2nd source for off of a direct current where begin to pass a current from said control electrode, and a current value is smaller than said 1st source for off of a direct current, The switch means which switches said 1st source for off of a direct current, and said 2nd source for off of a direct current, An on-off switch means to switch said source for ON of a direct current, and the output of said 1st switch means, and to connect with said control electrode, A switching signal generating means to supply a signal to said on-off switch means, It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case the electrical potential difference of said control electrode is reduced and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. With the output of said current reduction start point detection means, said switch means is operated so that said 2nd source for off of a direct current may be used in said 2nd period using said 1st source for off of a direct current in said 1st period.

[0013] The drive circuit of the semiconductor device concerning the 5th configuration of this invention In the drive circuit connected to the control electrode of the insulated-gate form self-**** component which controls the switch-on between main electrodes by the electrical potential difference impressed to a control electrode The direct current voltage supply for ON which supply ON state voltage to said control electrode, and the direct current voltage supply for off which supply OFF state voltage to said control electrode, The on-off switch means which switches said direct current voltage supply for ON and said direct current voltage supply for off, A switching signal generating means to supply a signal to said on-off switch means, The gate resistance connected between said on-off switch means and said control electrodes, The capacitor which was connected to said control electrode and which switched and was connected with the means and said switch means between the ends of said main electrode, The voltage adjustment means connected to said switch means and juxtaposition, The electrical potential difference impressed to said control electrode It has a current reduction start point detection means to detect the reduction start point of a current in case change of the current to which change of the current which flows to said main electrode in case it is made to fall and between said main electrodes is made to change from switch-on to non-switch-on follows it from the 1st slow period changes at the 2nd ****** period. Said switch means is operated so that said control electrode and said capacitor may be connected in said 2nd period with the output of said current reduction start point detection means.

[0014] The drive circuit of the semiconductor device concerning the 6th configuration of this invention consists of a comparison means by which said current reduction start point detection means measures an electrical-potential-difference detection means to detect the electrical

potential difference of the control electrode of said insulated-gate form self-**** component, the source of reference voltage, and the output of said electrical-potential-difference detection means and the output of said source of reference voltage.
[0015] The drive circuit of the semiconductor device concerning the 7th configuration of this invention consists of a comparison means by which said current reduction start point detection means measures a current detection means to detect the current which flows to the control electrode of said insulated-gate form self-**** component, the source of reference voltage, and the output of said current detection means and the output of said source of reference voltage.
[0016] The drive circuit of the semiconductor device concerning the 8th configuration of this invention consists of a comparison means to by_which said current reduction start point detection means measures an electrical-potential-difference detection means detect the electrical potential difference of the control electrode of said insulated-gate form self-**** component, a differential means differentiate the output of said electrical-potential-difference detection means, the source of reference voltage, and the output of said differential means and the output of said source of reference voltage.
[0017] The drive circuit of the semiconductor device concerning the 9th configuration of this invention consists of a comparison means to by_which said current reduction start point detection means measures a current detection means detect the current which flows the control electrode of said insulated-gate form self-**** component, a differential means differentiate the output of said current detection means, the source of reference voltage, and the output of said differential means and the output of said source of reference voltage.
[0018]
[Embodiment of the Invention]
The gestalt of implementation of the 1st of this invention is explained about drawing below gestalt 1. of operation. In case an IGBT component is made to change from an ON state to an OFF state using drawing 2 and drawing 3 first, the reduction start point of a current in case change of the current to which change of the current which flows for an IGBT component follows it from the 1st slow period changes at the 2nd ****** period is explained. Drawing 2 is an example of a switching circuit and drawing 3 is the electrical potential difference of the IGBT component 1 in the switching circuit of drawing 2 , and the wave form chart of a current. For gate resistance and 15, as for a load and 17, in drawing 2 , direct current voltage supply and 16 are [9 / reflux diode and 18] wiring inductances. Since it is the same as the drive circuit of the semiconductor device by the Prior art of drawing 18 about 1 to 5, explanation is omitted. If the switching signal generating means 4 outputs an ON signal, it is switched to the direct current voltage supply 2 for ON, ON state voltage is impressed to the gate of the IGBT component 1 through gate resistance 9, and the on-off switch means 5 turns on the IGBT component 1. When the IGBT component 1 turns on, the electrical potential difference Vdc of direct current voltage supply 15 is impressed to a load 16, and they are direct current voltage supply 15. - A current flows in the path of the wiring inductance 18-load 16-IGBT component 1-direct current voltage supply 15. The electrical potential difference of the IGBT component 1 at this time and the current are expressed with drawing 3 in respect of time of day 0. Since the IGBT component 1 is turned on in time of day 0, collector to emitter voltage Vce is 0, and that of collector current Ic is equal to the current IL of a load 16. Since it is a capacitor between the gate-emitters of the IGBT component 1, if ON time amount excels enough, the electrical potential difference Vge between gate-emitters will be charged to the electrical potential difference of the direct current voltage supply 2 for ON, and gate current Ig will be set to 0. Subsequently, if the switching signal

generating means 4 outputs an off signal in time of day t1, the on-off switch means 5 will be switched to the direct current voltage supply 3 for off, and OFF state voltage will be impressed to the gate of the IGBT component 1 through gate resistance 9. Since drawing 3 is setting the direct current voltage supply 3 for OFF to 0, the electrical potential difference Vge between gate-emitters starts reduction with the time constant which goes to 0 (capacitor between gate-emitters of the gate resistance 9xIGBT component 1). However, since it is set up highly enough to the ON state voltage needed in order that the direct current voltage supply 2 for ON may pass the load current IL, actual turn-off actuation of the IGBT component 1 is not usually performed until it reaches the minimum electrical potential difference Von needed for the electrical potential difference Vge between gate-emitters passing the load current IL in time of day t2. In time of day t2, if the electrical potential difference Vge between gate-emitters reaches the electrical potential difference Von needed for passing the load current IL, the IGBT component 1 will start turn-off actuation, and collector to emitter voltage Vce will increase it. Although the electrical potential difference impressed to a load 16 turns into an electrical potential difference which subtracted collector to emitter voltage Vce from the electrical potential difference Vdc of direct current voltage supply 15 at this time, since it is an inductance load, the current IL which flows a load 16 does not change suddenly. For this reason, collector current Ic does not change suddenly, either but collector current Ic forms the 1st period when change of a current is slow. In this 1st period, the feedback operation which is going to maintain the electrical potential difference Vge between gate-emitters at the electrical potential difference Von needed for passing the load current IL works so that collector current Ic may not be changed, and the electrical potential difference Vge between gate-emitters turns into an almost fixed electrical potential difference. The displacement current flows from a collector to the gate through the capacitor between the collector-gates of the IGBT component 1 by the increment in collector to emitter voltage Vce, and this feedback operation is realized when this displacement current produces a voltage drop in gate resistance 9. Since this displacement current is exactly gate current, it turns into a current also with almost fixed gate current Ig. In time of day t3, if collector to emitter voltage Vce reaches the electrical potential difference Vdc of direct current voltage supply 15, the reflux diode 17 turns on, and the current which flows a load 16 starts commutation to the reflux diode 17. Only the part of the current Id commutated to the reflux diode 17 forms the 2nd period ****** [collector current / Ic] in change of a current, in order that collector current Ic may decrease. In this 2nd period, the feedback operation which is going to keep constant the above-mentioned electrical potential difference Vge between gate-emitters is lost, and the electrical potential difference Vge between gate-emitters starts reduction toward 0 again. Therefore, gate current Ig decided by the electrical potential difference Vge between gate-emitters and gate resistance 9 also decreases. Moreover, since collector current Ic is equal to the current which flows to the wiring inductance 18, the current which flows to the wiring inductance 18 in this 2nd period also decreases. For this reason, the wiring inductance 18 generates the electrical potential difference expressed with (wiring inductance x current percentage reduction). Since this electrical potential difference is direct current voltage supply 15 and like-pole nature, it serves as a wave superimposed on the electrical-potential-difference surge which the wiring inductance 18 generates in direct current voltage supply 15 at collector to emitter voltage Vce. In time of day t4, if the electrical potential difference Vge between gate-emitters reaches the threshold Vth of the IGBT component 1, collector current Ic will be set to 0 and the IGBT component 1 will complete turn-off actuation. Although actual turn-off actuation is completed after time of day t4, since the electrical potential difference Vge between gate-emitters does not amount to 0 yet, it continues reduction toward 0

succeedingly. In time of day t5, the electrical potential difference Vge between gate-emitters amounts to 0, and all actuation is completed. In turn-off actuation of the above IGBT component 1, a current reduction start point is defined as the time of the boundary t3 of the 1st period (from t2 to t3) when change of collector current Ic is slow, and the 2nd period (from t3 to t4) ****** in change of the collector current Ic generated following on it, i.e., time of day, by this invention. If another definition is carried out, a current reduction start point is almost equal to the time of day when the 2nd order fine multiplier of collector current Ic serves as max.

[0019] Next, the configuration of the gestalt 1 of operation of this invention is explained about drawing 1 R> 1. In drawing 1 , 12 is the 1st driving means, 13 is the 2nd driving means, and the 2nd driving means 13 drives the IGBT component 1 rather than the 1st driving means 12 at a low speed. In case a switch means for 11 to switch the output of the 1st driving means 12 and the output of the 2nd driving means 13, and to supply the gate of the IGBT component 1, and 14 make the IGBT component 1 change from an ON state to an OFF state, they are a current reduction start point detection means detect the reduction start point of a current in case change of the current to which change of the current which flows for the IGBT component 1 follows it from the 1st slow period changes at the 2nd ****** period. Since it is the same as the drive circuit of the semiconductor device by the Prior art of drawing 18 about 1 and 4, explanation is omitted. The 1st and 2nd direct current voltage supply for ON which supply an electrical potential difference for 2a and 2b to turn on the IGBT component 1, The 1st and 2nd direct current voltage supply for off which supply an electrical potential difference for 3a and 3b to turn off the IGBT component 1, 5a and 5b with the output of the switching signal generating means 4 The 1st and 2nd direct-current-voltage-supply 2for ON a, As for the 1st which switches the 2b, 1st, and 2nd direct current voltage supplies 3a and 3b for off, respectively, and impresses an electrical potential difference to the gate of the IGBT component 1 and the 2nd on-off switch means, and 9, the 1st gate resistance and 10 are the 2nd gate resistance. The 2nd gate resistance 10 has large resistance rather than the 1st gate resistance 9.

[0020] Next, actuation is explained using drawing 1 and drawing 4 . The collector current Ic whose drawing 4 is the flow current of the IGBT component 1, and the collector to emitter voltage Vce of the IGBT component 1, Are illustrating switching loss P of the IGBT component 1, and drawing 4 (a) the case where the IGBT component 1 is driven by the 1st driving means 12 when gate resistance is small Drawing 4 (b) shows the case where drawing 4 (c) applies this invention for the case where the IGBT component 1 is driven by the 2nd driving means 13 when gate resistance is large, respectively. If the switching signal generating means 4 outputs an ON signal, it is switched to 1st and 2nd direct-current-voltage-supply 2for ON a, and 2b, respectively, ON state voltage is impressed to the gate of the IGBT component 1 through the 1st gate resistance 9 or 2nd gate resistance 10, and the 1st and 2nd on-off switch means 5a and 5b turn on the IGBT component 1. Subsequently, if the switching signal generating means 4 outputs an off signal, it is switched to the 1st and 2nd direct current voltage supplies 3a and 3b for off, respectively, OFF state voltage is impressed to the gate of the IGBT component 1 through the 1st gate resistance 9 or 2nd gate resistance 10, and the 1st and 2nd on-off switch means 5a and 5b turn off the IGBT component 1. Under the present circumstances, change of collector current Ic switches with the output of the current reduction start point detection means 14 in the 1st slow period, a means 11 is switched to the 1st driving means 12, and the IGBT component 1 drives in the condition that the gate resistance shown in drawing 4 (a) is small. Moreover, change of collector current Ic switches with the output of the current reduction start point detection means 14 in the 2nd ****** period, a means 11 is switched to the 2nd driving means 13, and the IGBT

component 1 drives in the condition that the gate resistance shown in drawing 4 (b) is large. Consequently, as shown in drawing 4 (c), an electrical potential difference equivalent to drawing 4 (a) and a current wave form are acquired before a current reduction start point, and an electrical potential difference equivalent to drawing 4 (b) and a current wave form are acquired after a current reduction start point. Therefore, according to the drive circuit of the semiconductor device in this invention, in the 1st period which is not related to an electrical-potential-difference surge, the IGBT component 1 is driven at high speed, and switching loss P is reduced, and the IGBT component 1 is driven in the 2nd period related to an electrical-potential-difference surge at a low speed, and an electrical-potential-difference surge can be controlled.
[0021] gestalt 2. of operation -- the configuration of the 2nd of the gestalt of operation of this invention is shown in drawing 5 . In drawing 5 , as for a gate resistance switch means and 9, the 1st gate resistance and 10 are the 2nd gate resistance, and 6 has resistance with the 2nd larger gate resistance 10 rather than the 1st gate resistance 9. Resistance for 9a to acquire resistance equivalent to the 1st gate resistance 9 by parallel connection and 10a are resistance for acquiring resistance equivalent to the 2nd gate resistance 10 by series connection. About other elements, since it is the same as the drive circuit of the semiconductor device by the Prior art of drawing 18 , or the gestalt 1 of operation of drawing 1, explanation is omitted.
[0022] Next, actuation is explained using drawing 5 (a). If the switching signal generating means 4 outputs an ON signal, it is switched to the direct current voltage supply 2 for ON, ON state voltage is impressed to the gate of the IGBT component 1 through the 1st gate resistance 9 or 2nd gate resistance 10, and the on-off switch means 5 turns on the IGBT component 1. Subsequently, if the switching signal generating means 4 outputs an off signal, it is switched to the direct current voltage supply 3 for off, OFF state voltage is impressed to the gate of the IGBT component 1 through the 1st gate resistance 9 or 2nd gate resistance 10, and the on-off switch means 5 turns off the IGBT component 1. Under the present circumstances, first, in the 1st period when change of collector current Ic is slow, the switch means 11 of the gate resistance switch means 6 is switched to the 1st gate resistance 9 by the output of the current reduction start point detection means 14, and the IGBT component 1 drives in the condition that gate resistance is small. Subsequently, change of collector current Ic switches with the output of the current reduction start point detection means 14 in the 2nd ****** period, a means 11 is switched to the 2nd gate resistance 10, and the IGBT component 1 drives in the condition that gate resistance is large. Consequently, in the 1st period which is not related to an electrical-potential-difference surge, the IGBT component 1 is driven at high speed, and switching loss P is reduced, and the IGBT component 1 is driven in the 2nd period related to an electrical-potential-difference surge at a low speed, and an electrical-potential-difference surge can be controlled.
[0023] Next, actuation is explained using drawing 5 (b). About the actuation of those other than gate resistance switch means 6, since it is the same as drawing 5 (a), explanation is omitted. In the case of the turn-off of the IGBT component 1, first, in the 1st slow period, change of collector current Ic switches with the output of the current reduction start point detection means 14, changes a means 11 into a short circuit condition, and uses the combined resistance of resistance 9a and the 2nd gate resistance 10 as gate resistance. Since parallel connection of resistance 9a and the 2nd gate resistance 10 is carried out, combined resistance becomes smaller than the 2nd gate resistance 10. At this time, resistance 9a is chosen so that it may change with resistance 9a and resistance with the combined resistance of the 2nd gate resistance 10 equal to the 1st gate resistance 9 of drawing 5 (a). In the 1st period, the IGBT component 1 drives in the condition that gate resistance is small, by this actuation. Subsequently, in the 2nd ****** period,

change of collector current Ic switches with the output of the current reduction start point detection means 14, changes a means 11 into an open condition, and uses only the 2nd gate resistance 10 as gate resistance. In the 2nd period, the IGBT component 1 drives in the condition that gate resistance is large, by this actuation. Consequently, in the 1st period which is not related to an electrical-potential-difference surge, the IGBT component 1 is driven at high speed, and switching loss P is reduced, and the IGBT component 1 is driven in the 2nd period related to an electrical-potential-difference surge at a low speed, and an electrical-potential-difference surge can be controlled.

[0024] Next, actuation is explained using drawing 5 (c). About the actuation of those other than gate resistance switch means 6, since it is the same as drawing 5 (a), explanation is omitted. In the case of the turn-off of the IGBT component 1, first, in the 1st slow period, change of collector current Ic switches with the output of the current reduction start point detection means 14, changes a means 11 into a short circuit condition, and uses the 1st gate resistance 9 as gate resistance. In the 1st period, the IGBT component 1 drives in the condition that gate resistance is small, by this actuation. Subsequently, in the 2nd ****** period, change of collector current Ic switches with the output of the current reduction start point detection means 14, changes a means 11 into an open condition, and uses the 1st gate resistance 9 and the combined resistance of resistance 10a as gate resistance. Since series connection of the 1st gate resistance 9 and the resistance 10a is carried out, combined resistance becomes larger than the 1st gate resistance 9. At this time, resistance 10a is chosen so that the 1st gate resistance 9 and the combined resistance of resistance 10a may change with resistance equal to the 2nd gate resistance 10 of drawing 5 (a). In the 2nd period, the IGBT component 1 drives in the condition that gate resistance is large, by this actuation. Consequently, in the 1st period which is not related to an electrical-potential-difference surge, the IGBT component 1 is driven at high speed, and switching loss P is reduced, and the IGBT component 1 is driven in the 2nd period related to an electrical-potential-difference surge at a low speed, and an electrical-potential-difference surge can be controlled.

[0025] gestalt 3. of operation -- the configuration of the 3rd of the gestalt of operation of this invention is shown in drawing 6 . In drawing 6 , 3a is the 1st direct current voltage supply for OFF, 3b is the 2nd direct current voltage supply for OFF, and the electrical-potential-difference value is set up so that the 2nd direct-current-voltage-supply 3b for OFF can impress a small negative electrical potential difference to the gate of the IGBT component 1 rather than 1st direct-current-voltage-supply 3a for OFF. As for direct current voltage supply for 3c to acquire an electrical-potential-difference value equivalent to 2nd direct-current-voltage-supply 3b for off by series connection, and 9, gate resistance and 19 are diodes. About other elements, since it is the same as the drive circuit of the semiconductor device by the Prior art of drawing 18 , or the gestalt 1 of operation of drawing 1, explanation is omitted.

[0026] Next, actuation is explained using drawing 6 (a). If the switching signal generating means 4 outputs an ON signal, it is switched to the direct current voltage supply 2 for ON, ON state voltage is impressed to the gate of the IGBT component 1 through gate resistance 9, and the on-off switch means 5 turns on the IGBT component 1. Subsequently, if the switching signal generating means 4 outputs an off signal, it is switched to 1st direct-current-voltage-supply 3for off a, or 2nd direct-current-voltage-supply 3b for off, OFF state voltage is impressed to the gate of the IGBT component 1 through gate resistance 9, and the on-off switch means 5 turns off the IGBT component 1. Under the present circumstances, change of collector current Ic switches with the output of the current reduction start point detection means 14 in the 1st slow period first, a means 11 is switched to 1st direct-current-voltage-supply 3a for off, and the IGBT component

1 drives in the condition that OFF state voltage is large. Subsequently, change of collector current Ic switches with the output of the current reduction start point detection means 14 in the 2nd ****** period, a means 11 is switched to 2nd direct-current-voltage-supply 3b for off, and the IGBT component 1 drives in the condition that OFF state voltage is small. Since it is a capacitor between the gate-emitters of the IGBT component 1, when it drives by the same gate resistance, the effectiveness that the one where OFF state voltage is smaller is the same with the percentage reduction of the electrical potential difference between gate-emitters having become small, and having enlarged gate